REMARKS

Claims 1-63 are pending. Claims 28-31 and 58-63 have been examined, and the remaining claims have been withdrawn from consideration. All examined claims have been rejected.

Applicant thanks the Examiner for the telephonic interview conducted on January 18, 2005. The substance of this interview is reflected in the remarks below.

Claim Rejections - 35 U.S.C. § 112

Claims 29-31 and 58-63 are rejected under 35 U.S.C. § 112, second paragraph, as being incomplete. While Applicant does not agree with this rejection, Applicant has nonetheless amended the claims in an attempt to satisfy the Examiner's concerns. The claims amendments involve features that were mainly already inherent in the claims, and thus should be entered. Withdrawal of this rejection is therefore respectfully requested.

Claim Rejections - 35 U.S.C. §§ 102 and 103

Claims 28 and 58 are rejected under 35 U.S.C. § 102(b) as being anticipated by Davidovoci (U.S. Patent No. 5,802,102). Claims 28, 58-61, and 63 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Kim et al. (U.S. Patent No. 6,219,374) in view of Critchlow (U.S. Patent No. 5,276,706). Applicant respectfully traverses these rejections for the same reasons as stated in the previous response. These reasons, along with additional comments, follow.

The present invention is directed to a configurable receiver for a CDMA system, which has an RF/IF stage 102 for receiving an analog signal, an analog-to-digital converter 104 for converting the analog signal to a digital signal, a chip-matched filter 108 for filtering the digital signal, and at least one configurable digital coherent demodulator system 110 for feed forward phase correcting the filtered digital signal. The invention also relates to a method of processing data using this configurable CDMA receiver. Because the phase error is corrected in the forward direction, the phase of the data signal is corrected in real time. Thus, the present invention provides an advantage

over conventional systems using feedback timing wherein data signals are corrected for a past phase error.

Davidovici is directed to a programmable matched filter which despreads a pilot-chip-code-sequence signal and a message-chip-code-sequence signal. The Examiner directs Applicant to Fig. 1, which the Examiner alleges teaches a means for receiving an analog signal at an RF/IF stage 31-34, an analog-to-digital converter 33, 34, a filter for filtering the digital signal 35, 37 to obtain a complex signal, and a demodulator 41, 46, 38, 39 for processing the complex signal output from the filters 35, 37 using correction signals from MF controller 46.

Contrary to the Examiner's position, Davidovici does not teach a configurable digital coherent demodulator system for feed forward phase correcting a filtered digital signal. Assuming for the sake of argument that the MF controller 46 outputs correction signals as the Examiner suggests, these signals are fed backward in the demodulator to various components rather than forward. These signals therefore can not be feedforward signals.

Feedforward control is a basic form of process control defined in McGraw-Hill Dictionary of Scientific and Technical Terms, Sixth Edition, page 784 (copy enclosed) as a "Process control in which changes in a system are detected at the process input and an anticipating correction signal is applied before the process output is detected." On the other hand, feedback control is defined in Modern Dictionary of Electronics, Sixth Edition, page 366 (copy enclosed) as "A type of system control obtained when a portion of the output signal is operated upon and fed back to the input in order to obtain a desired effect."

The difference between feedforward and feedback control is illustrated in "Lecture 16 - Controller Structures" by K. J. Anstrom found at http://www.control.lth.se/~kja/nybok/lectures/fourslides2001/lecture16.pdf (copy enclosed). As clearly shown on page 2 of this lecture, feedforward control involves the control signal u being fed forward in the system, bypassing the process G_v to the summer. Conversely, feedback control involves the control signal y being fed backwards in the system from the output through the process

"-1", and back to the summer. Many other examples illustrating the difference between feedforward and feedback control may be found on the internet.

Turning back to the Davidovici reference, the Examiner asserts on page 8 of the Office Action that Davidovici's demodulator 41, MF controller 46, and filters 38 and 39 have control signals, which the Examiner considers to be correction signals which the Examiner says accounts for feedforward correcting a filtered digital signal. Applicant respectfully disagrees. Even if these elements have control or correction signals, it does not necessarily follow that these signals are fed forward. As asserted above, Davidovici does not teach or suggest feeding correction signals forward. Davidovici only feeds signals backward. The signals output from the MF controller 46 are fed back to elements upstream in the circuit rather than being fed forward to elements downstream in the circuit, and thus can not be feedforward signals. Thus claims 28 and 58 are patentable over Davidovici for at least this reason.

Kim is directed to a coherent dual channel quadrature phase shift keying transceiver using pilot symbols in a code division multiple access system. The Examiner directs Applicant to Fig. 3 and alleges that Kim teaches a means for receiving an analog signal at an RF/IF stage 301, a filter for filtering the analog signal using a matched filter 303, 304 to obtain a complex signal, and a demodulator 305-318 for processing the complex signal output from the filters 303, 304 using correction signals output from the channel estimators 317, 318 and fed forward to elements represented by reference numerals 306 and 307. The Examiner admits that Kim does not teach an analog-to-digital-converter. The Examiner attempts to make up for this deficiency by stating that Kim does not disclose whether or not the matched filter is a digital filter, and then cites Critchlow as teaching a digital matched filter 24, which would necessarily need a digital-to-analog converter to first convert the analog signal to digital format.

Contrary to the Examiner's position, there is no disclosure or suggestion in Kim that the channel estimators 317, 318 produce correction signals used by a demodulator to feed forward phase correct a filtered digital signal, as required by the claims of the present invention. Kim does disclose in column 4, lines 59-64, that the channel estimators 317, 318 produce signals used in the

channel estimation values upon data demodulation, but these values are fed backward in the circuit rather than forward. (The differences between feedforward and feedback are explained above, and do not bear repeating here.) There is no disclosure that these values are fed forward to correct a filtered digital signal, as required by the claims of the present invention.

Critchlow is directed a system and method for frequency acquisition in digital communication systems. The Examiner applies Critchlow as allegedly teaching converting an analog signal to a digital signal to be filtered by a matched filter. However, Critchlow fails to make up for Kim's deficiencies in that it does not suggest the claimed configurable digital coherent demodulator system for feed forward phase correcting a filtered digital signal. Thus, the claims are patentable over Kim and Critchlow for at least this reason.

In view of the above amendment, applicant believes the pending application is in condition for allowance.

Dated: February 14, 2005

Respectfully submitted,

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McGRAW-HILL DICTIONARY OF SCIENTIFIC AND TECHNICAL TERMS

Sixth Edition

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On the cover: Representation of a fullerene molecule with a noble gas atom trapped inside. At the Permian-Triassic sedimentary boundary the noble gases helium and argon have been found trapped inside fullerenes. They exhibit isotope ratios quite similar to those found in meteorites, suggesting that a fireball meteorite or asteroid exploded when it hit the Earth, causing major changes in the environment. *(Image copyright © Dr. Luann Becker. Reproduced with permission.)*

Over the six editions of the Dictionary, material has been drawn from the following references: G. M. Garrity et al., *Taxonomic Outline of the Procaryotes,* Release 2, Springer-Verlag, January 2002; D. W. Linzey, *Vertebrate Biology,* McGraw-Hill, 2001; J. A. Pechenik, *Biology of the Invertebrates,* 4th ed., McGraw-Hill, 2000; *U.S. Air Force Glossary of Standardized Terms,* AF Manual 11-1, vol. 1, 1972; F. Casey, ed., *Compilation of Terms in Information Sciences Technology,* Federal Council for Science and Technology, 1970; *Communications-Electronics Terminology,* AF Manual 11-1, vol. 3, 1970; P. W. Thrush, comp. and ed., *A Dictionary of Mining, Mineral, and Related Terms,* Bureau of Mines, 1968; *A DOD Glossary of Mapping, Charting and Geodetic Terms,* Department of Defense, 1967; J. M. Gilliland, *Solar-Terrestrial Physics: A Glossary of Terms and Abbreviations,* Royal Aircraft Establishment Technical Report 67158, 1967; W. H. Allen, ed., *Dictionary of Technical Terms for Aerospace Use,* National Aeronautics and Space Administration, 1965; *Glossary of Stinfo Terminology,* Office of Aerospace Research, U.S. Air Force, 1963; *Naval Dictionary of Electronic, Technical, and Imperative Terms,* Bureau of Naval Personnel, 1962; R. E. Huschke, *Glossary of Meteorology,* American Meteorological Society, 1959; *ADP Glossary,* Department of the Navy, NAVSO P-3097; *Glossary of Air Traffic Control Terms,* Federal Aviation Agency; *A Glossary of Range Terminology, White Sands Missile Range, New Mexico,* National Bureau of Standards, AD 467-424; *Nuclear Terms: A Glossary,* 2d ed., Atomic Energy Commission.

McGRAW-HILL DICTIONARY OF SCIENTIFIC AND TECHNICAL TERMS,
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feeder road [CIV ENG] A road that feeds traffic to a more important road. { 'fēd·ər ,rōd }

feeder trough [MIN ENG] The trough connected to the conveyor pan line in a duckbill. { 'fēd·ər ,tròf }

feeder yarn [TEXT] Yarn that is furnished to the throwing process. { 'fēd·ər ,yärn }

feedforward control [CONT SYS] Process control in which changes are detected at the process input and an anticipating correction signal is applied before process output is affected. { ¦fēd¦fȯr·wərd kən,trōl }

feedhead [MET] A reservoir of molten metal that is left above a casting in order to supply additional metal as the casting solidifies and shrinks. Also known as riser; sinkhead. { 'fēd,hed }

feed holes [COMPUT SCI] Holes along the edges of continuous-feed computer paper that are engaged by sprockets to move the paper and maintain alignment during printing. { 'fēd ,hōlz }

feed horn [ELECTROMAG] A device located at the focus of a receiving paraboloidal antenna that acts as a receiver of radio waves which the antenna collects, focuses, and couples to transmission lines to the amplifier. { 'fēd ,hȯrn }

feeding ground *See* drainage basin. { 'fēd·iŋ ,graủnd }

feeding mechanism [ZOO] A mechanism by which an animal obtains and utilizes food materials. { 'fēd·iŋ ,mek·ə,niz·əm }

feeding rod [MET] A rod used by working up and down to keep the passage clear between riser and casting. { 'fēd·iŋ ,räd }

feeding zone [CONT SYS] The area on the planar surface of a conveyor or pallet where the center of an object to be manipulated by a robotic system is placed. { 'fēd·iŋ ,zōn }

feed lines [MET] The pattern produced on the surface of a piece of metal by machine grinding. { 'fēd ,līnz }

feed materials [NUCLEO] Refined uranium or thorium metal or their pure compounds in a form suitable for use in nuclear reactor fuel elements or as feed for uranium-enrichment processes. { 'fēd mə,tir·ē·əlz }

feed nut [MECH ENG] The threaded sleeve fitting around the feed screw on a gear-feed drill swivel head, which is rotated by means of paired gears driven from the spindle or feed shaft. { 'fēd ,nət }

feed off [ENG] To lower the bit continuously or intermittently during a drilling operation by disengaging the drum brake. { ¦fēd 'ȯf }

feed pipe [MECH ENG] The pipe which conducts water to a boiler drum. { 'fēd ,pīp }

feed pitch [DES ENG] The distance between the centers of adjacent feed holes in punched paper tape. { 'fēd ,pich }

feed preparation unit [CHEM ENG] A processing unit (such as distillation or desulfurization units) providing feedstock for subsequent processing. { ¦fēd prep·ə'rā·shən ,yü·nət }

feed pressure [MECH ENG] Total weight or pressure, expressed in pounds or tons, applied to the drilling stem to make the drill bit cut and penetrate the geologic, rock, or ore formation. { 'fēd ,presh·ər }

feed pump [MECH ENG] A pump used to supply water to a steam boiler. { 'fēd ,pəmp }

feed rate *See* cutting speed. { 'fēd ,rāt }

feed ratio [MECH ENG] The number of revolutions a drill stem and bit must turn to advance the drill bit 1 inch when the stem is attached to and rotated by a screw- or gear-feed type of drill swivel head with a particular pair of the set of gears engaged. Also known as feed speed. { 'fēd ,rā·shō }

feed reel [ENG] The reel from which paper tape or magnetic tape is being fed. { 'fēd ,rēl }

feed screw [MECH ENG] The externally threaded drill-rod drive rod in a screw- or gear-feed swivel head on a diamond drill; also used on percussion drills, lathes, and other machinery. { 'fēd ,skrü }

feed shaft [MECH ENG] A short shaft or countershaft in a diamond-drill gear-feed swivel head which is rotated by the drill motor through gears or a fractional drive and by means of which the engaged pair of feed gears is driven. { 'fēd ,shaft }

feed shelf [COMPUT SCI] **1.** A device for supporting documents for manual sensing. **2.** The first few feet of a tape reel, used to prime the tape drive. { 'fēd ,shelf }

feed speed *See* feed ratio. { 'fēd ,spēd }

feedstock [ENG] The raw material furnished to ... or process. { 'fēd,stäk }

feedstuff [AGR] Food, usually of lower quality, ... mals. { 'fēd,stəf }

feed tank [ENG] A chamber that contains ... { 'fēd ,taŋk }

feed-tape [COMPUT SCI] A mechanism which will ... to be read or sensed. { 'fēd,tāp }

feedthrough [ELEC] A conductor that connects ... opposite sides of a printed circuit board. Also known ... face connection. { 'fēd ,thrü }

feedthrough capacitor [ELEC] A feedthrough ... provides a desired value of capacitance between the ... through conductor and the metal chassis or panel through ... the conductor is passing; used chiefly for bypass ... ultra-high-frequency circuits. { 'fēd,thrü kə'pas·əd·ər }

feedthrough insulator *See* feedthrough terminal. { ... 'in·sə,lād·ər }

feedthrough terminal [ELEC] An insulator designed for mounting in a hole in a panel, wall, or bulkhead, with a ... tor in the center on the insulator to permit feeding ... through the partition. Also known as feedthrough ... { 'fēd,thrü 'tərm·ən·əl }

feed track [COMPUT SCI] The longitudinal channel ... paper tape that contains the feed holes. { 'fēd ,trak }

feed travel [MECH ENG] The distance a drilling ... moves the steel shank in traveling from top to bottom ... feeding range. { 'fēd ,trav·əl }

feed tray [CHEM ENG] For a tray-type distillation column, that tray on which fresh feedstock is introduced into the ... { 'fēd ,trā }

feed trough [MECH ENG] A receptacle into which feed ... overflows from a boiler drum. { 'fēd ,tròf }

feedwater [MECH ENG] The water supplied to a boiler ... still. { 'fēd,wȯd·ər }

feedwater heater [MECH ENG] An apparatus that ... steam extracted from an engine or turbine to heat boiler feedwater. { 'fēd,wȯd·ər ,hēd·ər }

feeler gage [MECH ENG] A tool with many blades of different thickness used to establish clearance between parts ... gapping spark plugs. { 'fēl·ər ,gāj }

feeler pin [MECH ENG] A pin that allows a duplicating ... machine to operate only when there is a supply of ... { 'fēl·ər ,pin }

feel the bottom [NAV] The effect on a ship underway in shallow water which tends to reduce its speed, make it ... in answering the helm, and often make it sheer off course; the speed reduction is largely due to increased wave making resistance resulting from higher pressure differences due to restriction of flow around the hull; the increased velocity of the water flowing past the hull results in an increase in ... Also known as smell the bottom. { ¦fēl thə 'bäd·əm }

Fehling's reagent [ANALY CHEM] A solution of cupric sulfate, sodium potassium tartrate, and sodium hydroxide, used to test for the presence of reducing compounds such as sugars. { 'fāl·iŋz rē,ā·jənt }

Feinc filter [MIN ENG] A vacuum-type drum filter in which a system of parallel strings is used to carry the filter cake away from the drum, instead of the usual filter cloth. { ... ,fil·tər }

Feit-Thompson theorem [MATH] The proposition that every group of odd order is solvable. { ¦fīt ¦täm·sən ,thir·əm }

feldspar [MINERAL] A group of silicate minerals that make up about 60% of the outer 9 miles (15 kilometers) of the earth's crust; they are silicates of aluminum with the metals potassium, sodium, and calcium, and rarely, barium. { 'fel,spär }

feldspathic graywacke [PETR] Sandstone containing less than 75% quartz and chert and 15–75% detrital clay matrix, and having feldspar grains in greater abundance than rock fragments. Also known as arkosic wacke; high-rank graywacke. { fel'spath·ik 'grā,wak·ə }

feldspathic sandstone [PETR] Sandstone rich in feldspar; intermediate in composition between arkosic sandstone and quartz sandstone, made up of 10–25% feldspar and less than 20% matrix material. { fel'spath·ik 'san,stōn }

feldspathic shale [PETR] A well-laminated shale with more than 10% feldspar in the silt size and with a finer matrix of kaolinitic clay minerals. { fel'spath·ik 'shāl }

feldspathization [GEOL] Formation of feldspar in a rock ...

ın author whose name is familiar to engi-
.o-it-yourselfers, and hobbyists. His many
ɔn mechanics, electricity, electronics and
well-deserved reputation for making com-
.y understandable and enjoyable. Mr. Graf
ıics engineer and received his MBA at New
is a Senior Member of the IEEE, a licensed
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nse. He has been in the electronics industry
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MODERN DICTIONARY of ELECTRONICS

Rudolf F. Graf

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detected, the receiver can recreate the correct information without a retransmission. 2. A system of data transmission in which redundant bits generated at the transmitter are used at the receiving terminal to detect, locate, and correct any transmission errors before delivery to the data sink. Advantage of this system is that it does not require a feedback channel; therefore, it can be used with a one-way transmission system.

Federal Communications Commission —Abbreviated FCC. A board of seven commissioners appointed by the President under the Communications Act of 1934, having the power to regulate all interstate and foreign electrical communication systems originating in the United States, including radio, television, facsimile, telegraph, telephone, and cable systems.

federal telecommunications system — System of commercial telephone lines, leased by the government, for use between major government installations, for official telecommunications.

feedback — 1. In a transmission system or a section of it, the returning of a fraction of the output to the input. 2. In a magnetic amplifier, a circuit connection by which an additional magnetomotive force (which is a function of the output quantity) is used to influence the operating condition. 3. In a control system, the signal or signals returned from a controlled process to denote its response to the command signal. Feedback is derived from a comparison of actual response to desired response, and any variation is used as an error signal combined with the original control signal to help attain proper system operation. Systems employing feedback are termed closed-loop systems; feedback closes the loop. 4. Squeal or howl from speaker caused by speaker sound entering microphone of same recorder or amplifier. 5. The return of a portion of the output of a circuit or device to its input. With positive feedback, the signal fed back is in phase with the input and increases amplification, but may cause oscillation. With negative feedback, the signal is 180° out of phase with the input and decreases amplification but stabilizes circuit performance and tends to lower an amplifier's output impedance, improve signal stability and minimize noise and distortion. 6. The process of coupling some of the output of an amplifier back to its input. Negative feedback reduces the gain of an amplifier, but has compensating beneficial results. Positive feedback can be used to boost gain (regeneration), but usually results in oscillation. 7. The flow of information back into the control system so that actual performance can be compared with planned performance.

feedback admittance — In an electron tube, the short-circuit transadmittance from the output electrode to the input electrode.

feedback amplifier — An amplifier that uses a passive network to return a portion of the output signal to modify the performance of the amplifier.

feedback attenuation — In the feedback loop of an operational amplifier, an attenuation factor by which the output voltage is attenuated to produce the input error voltage.

feedback circuit — A circuit that permits feedback in an electronic device.

feedback compensation — The placement of a device, or an additional circuit, into a feedback control system to improve its response in relation to a specific characteristic of a system.

feedback control — 1. A type of system control obtained when a portion of the output signal is operated upon and fed back to the input in order to obtain a desired effect. 2. An automatic means of sensing speed variations and correcting to maintain a constant speed or close speed regulation. 3. Guidance technique used by robots to bring the end effector to a programmed point.

feedback control loop — A closed transmission path which includes an active transducer and consists of a forward path, a feedback path, and one or more mixing points arranged to maintain a prescribed relationship between the loop input and output signals.

feedback control signal — That portion of the output signal which is returned to the input in order to achieve a desired effect, such as fast response.

feedback control system — 1. A control system comprising one or more feedback control loops; it combines the functions of the controlled signals and commands, tending to maintain a prescribed relationship between the two. 2. A system designed to control the output quantity of a device by returning a portion of its output signal back to its input. This results in the manipulation of the input quantity so that the desired relationship between the input and output signals can be maintained.

feedback cutter — An electromechanical transducer which performs like a disc cutter except it is equipped with an auxiliary feedback coil in the magnetic field. Signals exciting the cutter are induced into the feedback coil, the output of which is fed back in turn to the input of the cutter amplifier. The result is a substantially uniform frequency response.

feedback diode — *See* Freewheeling Diode.

feedback loop — The components and processes involved in using part of the

Lecture 16 - Controller Structures

K. J. Åström

1. Introduction
2. Feedback and Feedforward
3. Linear Schemes
4. Nonlinear Schemes
5. Gain Scheduling and Adaptation
6. Summary

Theme: Building complex control systems.

Introduction

Many common issues in design of machines, electronics, computer software, mechatronics

- How to deal with complexity
- Modularization
- Standardization
- Structures
- Paradigms, Design principles
- Top Down and Bottom Up

Bottom Up Design

- A way to view systems
- A number of building blocks
- Ideas to combine them
- What are the building blocks of control?
- What principles can be used to select and combine them?
- The danger: Can it be done better?
- Commissioning: Close loops one by one.

Bottom Up Design of Control Systems

Components

- Controllers
- Observers
- Estimators
- Filters
- Limiters
- Dead zones
- Selectors

System principles

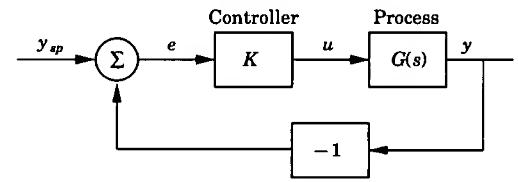
- Feedback
- Feedforward
- Model following
- Cascade
- Split range
- Gain scheduling
- Adaptation

Top Down Design of Control Systems

- Model complete system
- Design an integrated system
- System concepts
  - State feedback
  - Observers
  - Model predictive control
- Commissioning: Needs careful consideration.

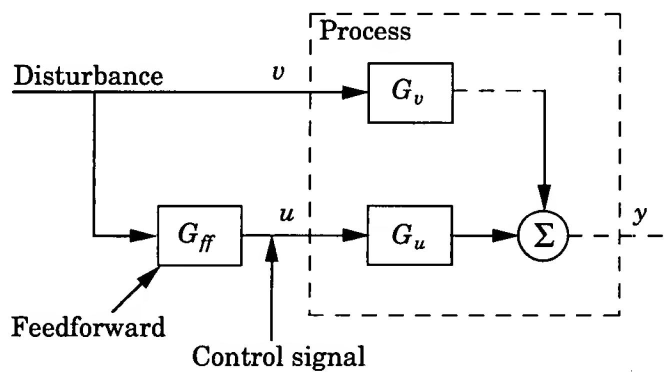
Feedback

A very powerful idea with dramatic impact



+ Reduce effect of disturbances
+ Reduce effect of process variations
+ Linearize nonlinear systems
+ Does not require accurate process model
- Measurement noise is injected into the system
- Risk for instability

Feedforward

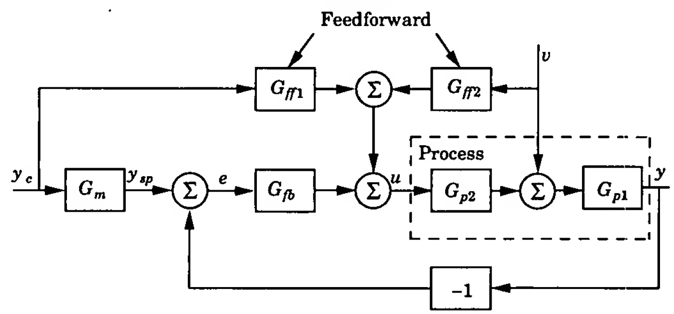


+ Reduce effects of disturbances that can be measured
+ Improve response to reference signals
+ No risk for instability
- Requires good models

Feedback and Feedforward

• Feedback	• Feedforward
• Closed loop	• Open loop
• Acts only when there are deviations	• Acts before deviations show up
• Market Driven	• Planning
• Robust to model errors $\|S\| < 1$ for some some frequencies	• Not robust to model errors $\|S\| = 1$ for all frequencies
• Risk for instability	• No risk for instability

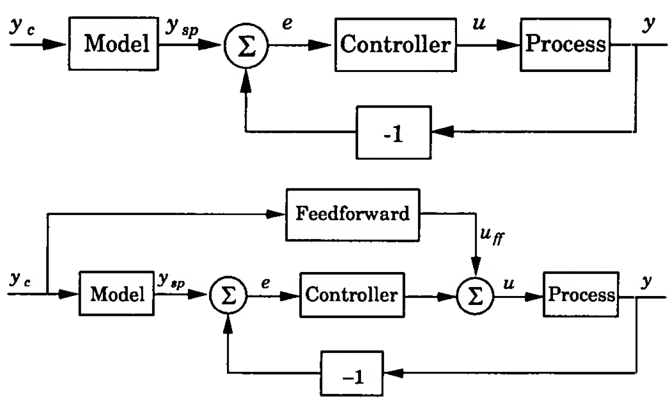
Combination of Feedback and Feedforward



Linear Schemes

- Model following - Systems with two degrees of freedom (2DOF)
- Filters
- Cascade control
- State feedback
- Observers
- Attenuation of disturbances with specific character
- The Smith Predictor
- Model Predictive Control

Model Following - 2DOF



Applications of Model Following

- Coordination in multi-axis motion control
- Robotics
- Path following
- Mixing in chemical processes
- Coordinated production changes

Filters

Typical filters

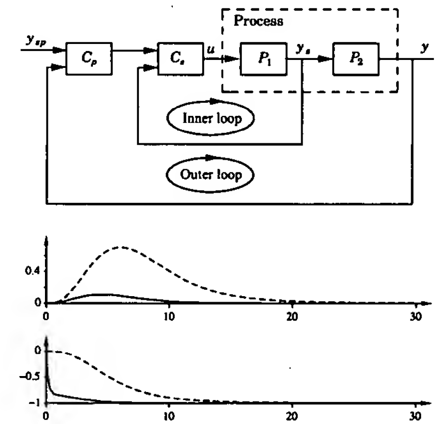
- Low pass
- High pass
- Band pass
- Notch
- Body bending filters

Typical applications

- Reduce disturbances
- Improve robustness (high frequency roll-off)
- Smooth reference signals

Cascade Control

How to use several sensors. State feedback is the ultimate case!



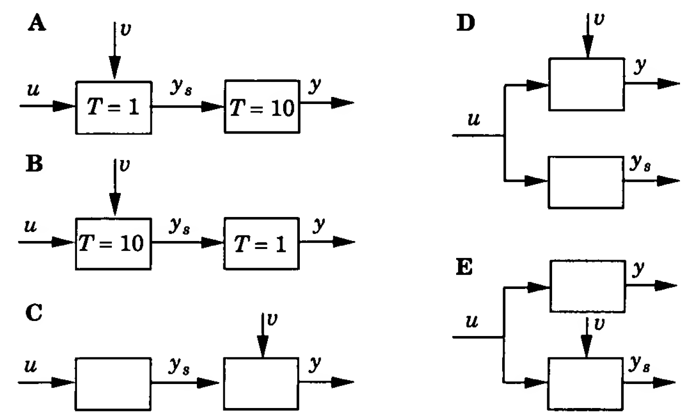
When is Cascade Control Useful?

Key idea: make tight feedback around essential places where there are essential perturbations (disturbances or uncertain-ties)

Guidelines:

- Well defined relation between primary and secondary variables
- Essential disturbances and process variations in inner loop
- Inner loop faster
- Tight feedback (high gain and high bandwidth) in inner loop

When is Cascade Control Useful?

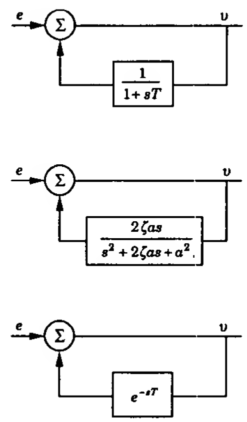


Attenuation of Disturbances with Specific Character

Idea: Exploit model of disturbances (internal model principle)

- Constant disturbances (Integral Action)
- Sinusoidal disturbances
- Periodic disturbances

A disturbance observer is an alternative.



Systems with Time Delays

- The derivative of the output gives poor prediction for systems with time delay
- Better predictions are possible by using past control signals $u(t-\tau), \quad 0 < \tau < T)_d$

Replace the regular PID controller

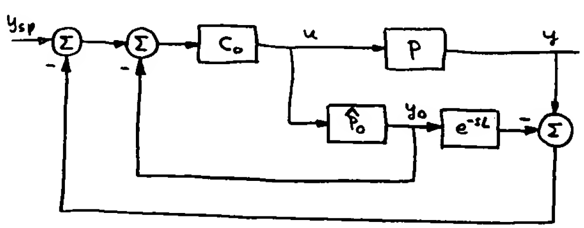
$$u = ke + \frac{1}{k_i}\int^t e(s)ds - k_d \frac{dy_f}{dt}$$

by the PPI (Predictive PI) controller

$$u = ke + \frac{1}{k_i}\int^t e(s)ds - k_p \int_{t-L}^t u(s)ds$$

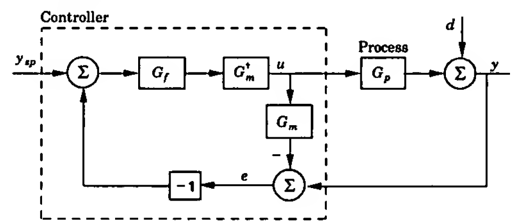
A simple form of the Smith predictor

The Smith Predictor



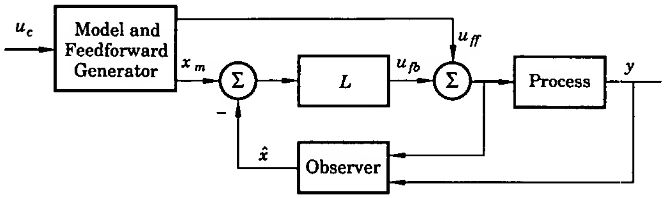
Design controller C as if there were no time delays in the process.

Model Predictive Control



- Beautifully simple
- Are there some snags?
  - Cancellations may degrade performance
  - Does not work if process is unstable
  - Less general than state feedback
- Widely used in process industries

State Feedback and Observers



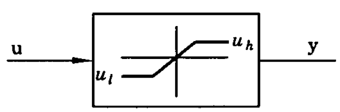
- Use model to estimate variables that are not directly measurable
- States are the variables required to account for storage of mass, momentum and energy
- Estimate the state
- Feedback from full state deviation
- Feedforward to generate u_m and y_m

Limiters

Limiters are often used

- To avoid saturation
- An element in circuits for windup protection
- To protect equipment to rapid changes

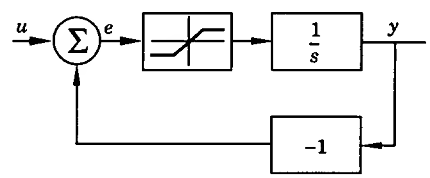
A simple amplitude limiter

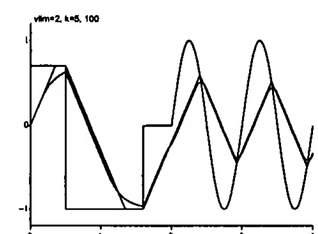


Nonlinear Schemes

- Limiters
- Split range
- Ratio control
- Selectors
- Fuzzy control
- Gain scheduling
- Neural networks
- Adaptation

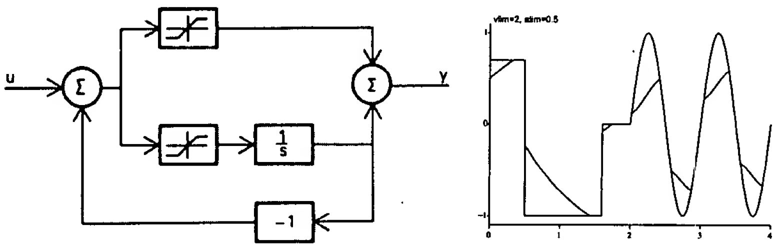
Rate Limiter





A rate limiter causes delays (JAS)

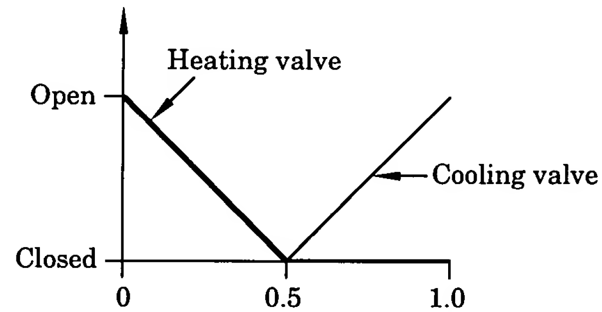
Jump and Rate Limiter



Commonly used in the power industry for load changes to save boilers.

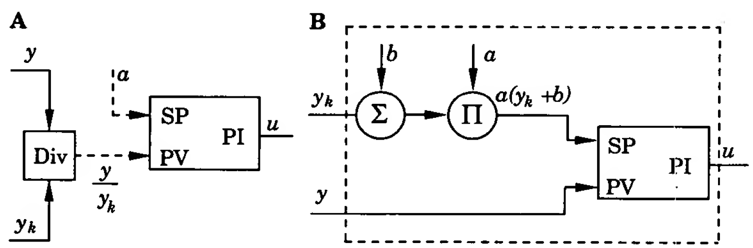
Split Range

A simple way to use one controller to control two actuators. Commonly used for heating and cooling.



Ratio Control

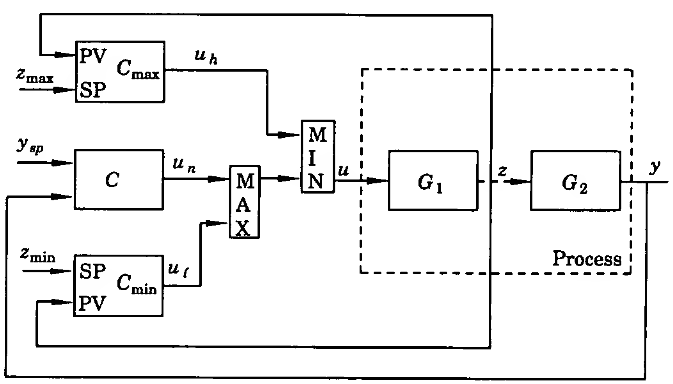
Arrangement to obtain two flows that are proportional to each other, e.g. oil and air in boilers



The scheme B is preferable! Why?

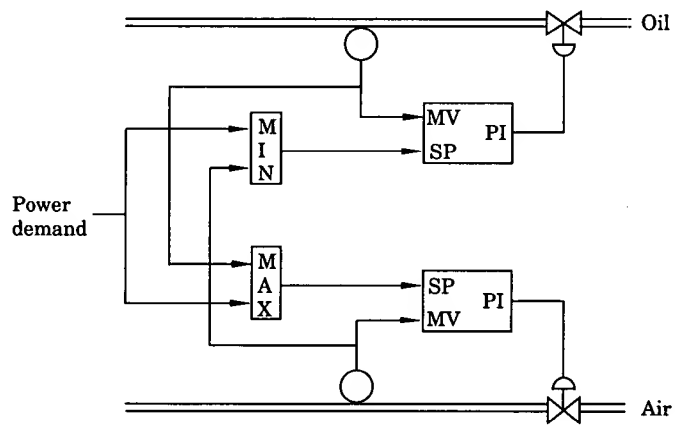
Selector Control

Scheme used to achieve several control objectives, e.g. control temperature unless pressure is too high. A way to constrain process variables during operation.



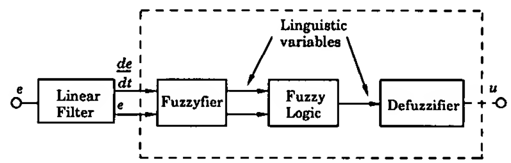
Control of Fuel and Air in a Boiler

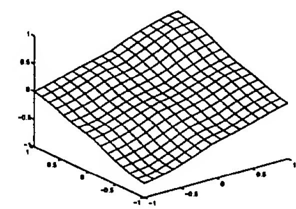
An elegant solution



Fuzzy Control

- Rule based control
- Linguistic variables *high, low, medium*
- Membership functions
- If temperature *high* then increase flow *a little*





Fuzzy Control

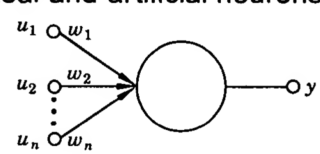
- A nonlinear state feedback
  - How do we get the states?
  - What does the nonlinearity look like?
  - Rules and interpolation
  - Why so few rules
  - When is it useful
- Excellent to automate successful manual operations
- Intuitive
- A lot of controversy: The *No Model Myth*
- Fuzzy control is more useful than its detractors claim but less useful than the propagandists claim
- Neuro-fuzzy

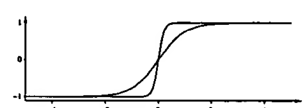
Neural Networks

Representation of functions of many variables

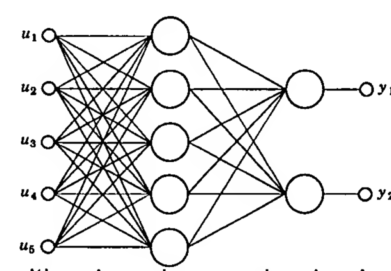
$$y(t) = f\left(\sum a_i u_i(t)\right)$$

Real and artificial neurons



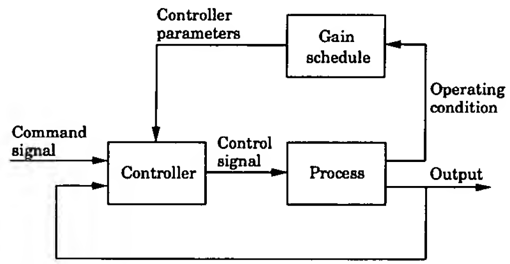


Feedforward neural network



A nonlinear function with a learning mechanism!

Gain Scheduling



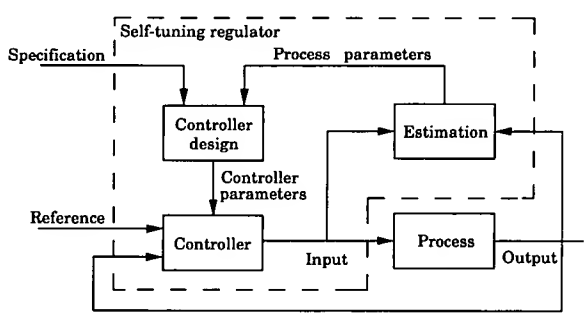
Example of scheduling variables

- Production rate
- Machine speed
- Mach number and dynamic pressure
- Room occupancy

Uses of Gain Scheduling

- Many uses
  - Linearization of actuators
  - Surge tank control
  - Control over wide operating regions
- Important issues
  - Choice of scheduling variables
  - Granularity of scheduling table
  - Interpolation schemes
  - Bump-less parameter changes
  - Man machine interfaces
- Importance of auto-tuning

Adaptation



- Certainty Equivalence
- Many control and estimation schemes
- Dual control
  - Control should be directing as well as investigating!

Uses of Adaptation

- Tuning Tools
- Automatic Tuning
- Gain Scheduling
- Adaptive feedback
- Adaptive feedforward
- Integrated systems